# TASK 7 - FARSIDE COUNTERMEASURES

## Introduction

The aim of Task 7 — Test Countermeasures of the ARC Far Side Collaborative Research Program, MUARC (2003) — was to identify and evaluate a range of generic in-vehicle countermeasure aimed at offering far side occupants improved protection in a side impact collision.

In developing a range of countermeasures, Task 7 intended to bring together most of the research findings from the previous 6 tasks. Listed below, shortly described, are the main implications (concerning Task 7) from each task.

**Task 1 – Injury&Harm** revealed the prioritized body regions: head, chest and upper and lower extremities. Also, AIS3+ and fatal risk curves were provided.

**Task 2 – Biomechanical test program** gave an understanding of the mechanisms of injury as well as how the occupant interacts with the belt and car interior.

**Task 3 – Neck injury research** offered an understanding of the mechanisms of direct and indirect injury mechanisms (tension and pinching) as well as a numerical model that can be used to assess risk.

**Task 4 – Dummy development** selected applicable far side crash test dummies namely the WorldSID and Thor. Also, task 4 showed shortcomings of these dummies (WS: belt interaction, Thor: side load).

**Task 5 – Test procedures and injury criteria** recommended test procedures in terms of full scale as well as sled tests. Examples of full scale tests were near-side full scale tests including a second front-seat dummy. Examples of sled tests were pre-deformed car interior fastened on a sled in a 90 or 70 degree angle. Also, a set of dummy injury criteria with associated risk curves were established.

**Task 6 – Model development** provided a model to be used for assessing countermeasures which for example was used to gain insight in the factors influencing the occurrence of belt-slipping.

## 1. Countermeasures

The three point belt is indeed a countermeasure for preventing far side occupant injuries. Nevertheless, three-point belt-restrained far side struck occupants are primarily restrained only by the lap portion of the belt and is far from a guarantee not to be injured. Sled tests and full-scale crash tests (Digges and Dalmotas, 2001; Fildes et al, 2002; Bostrom et al 2003) have shown that, in a side impact, the far side occupant may slide out of the seat belt and flails toward the struck side of the vehicle. In real world crashes, the occupant then may collide with the surfaces or objects on the nearside including the intruded nearside door, the adjacent seat, and the nearside occupant.

Several far side impact injury countermeasures, for three point belted occupants, have been proposed and evaluated. The countermeasures include belt pretensioning (Stolinski et al, 1999; Douglas et al, 2007), the side support airbag (SSA) (Bostrom and Haland, 2005), reversed geometry

**Table 1. List, feature, examples, test specifications and references of examples of concepts of far side countermeasures.**

| Countermeasure | Feature | Examples | $\Delta v$, angle, dummy | Reference |
|---|---|---|---|---|
| **Belt pretensioner** | Reduce slack and tighten the belt by various degrees | Pyrotechnical and electrical retractor, buckle and latch plate pretensioners | 30 km/h, 30-90 deg, Numerical model of human | Douglas et al 2007 |
| **Inboard side support** | Restrain the occupant from moving inboard | Side support airbags, side support wings | 24 km/h, 60&90 deg, BioSID spring spine | Bostrom and Haland, 2005 |
| **Altered 3-point belt geometry** | Restrain the occupant from moving inboard | Criss-cross, reversible 3-point, rucksack-belt, V-shaped 4-point belt (V4) | 24 km/h, 60&90 deg, BioSID spring spine | Bostrom and Haland, 2005 |
| | | | About 24 km/h (FMVSS214) Post-Mortem Human Subjects | Rouhana et al 2006 |
| | | | 30 km/h, 90 deg, Thor | Bostrom et al 2008 |
| **Nearside head and thorax airbags** | Provide cushioning between deformed struck side and occupant | Head and thorax airbags, inflatable curtain, window bags | 50 km/h, 90 deg, WorldSID | Bostrom et al 2008 |

shoulder belts (Bostrom et al, 2005), criss-cross shoulder belts (Bostrom and Haland, 2005), the V-shaped 4-point belt (Rouhana et al, 2003 and 2006), inflatable curtains (Kahane 2007) and even an adjacent occupant (Frampton et al, 1998). Table 1 (from Bostrom et al 2008) lists most of the proposed countermeasures including references.

Advanced belt systems such as criss-cross belts, V-shaped 4-point (V-4) belts or rucksack belts, shown in Figure 1, would benefit not only far side struck occupants, but occupants subjected to frontal impacts as well. In a frontal impact, the more symmetrical, thoracic loading provided by these belt systems may help to reduce thoracic injuries (Bostrom and Haland, 2005; Rouhana et al, 2003). It is important though to design these belts not to cause new injury patterns such as neck injuries. Research is underway to gauge the potential for any restraint to cause neck injuries (Fildes et al 2005).

**Figure 1. Three versions of altered 3-point belt geometry, criss cross, V4 and rucksack (from Bostrom et al 2008)**

Seat belt systems, which improve restraint of the far side occupant, may also benefit the nearside occupant. In a side crash where there are two adjacent front seat occupants, the nearside occupant may be struck on one side by the deformed side structure and on the opposite side by the adjacent, far side, occupant.

It is critical to understand that median injury test conditions may represent only a minimal injury risk. Consequently, tests conducted under these conditions may result in low injury assessment outcomes. Injury incidence is a result of both exposure and risk. For this reason it is crucial to determine exposure and risk as a function of crash severity to compute the opportunities of countermeasures.

## 2.Opportunities

### 2.1 No Interaction with Passenger

Within the program, Bostrom et al estimated the opportunities of altered seat belts, side support airbags and inflatable side curtains for belted far side occupants in planar side impact crashes. The analysis was based on real life crash analysis and mechanical simulations of occupant motion. Examples of countermeasure performance are shown in Figures 2-4 where a BioSID with spring spine, a Thor and a WorldSID 50% percentile are used as far side dummy.

**Figure 2. Photographs taken at 1, 75 and 150 ms from the Bostrom et al 2005 side support airbag test with a BioSID spring spine at 90 degrees and Δv 24 km/h.**

**Figure 3. Photographs at 1, 75 and 150 ms from tests with a Thor restrained by an extra belt (no load limiting) at 90 degrees and Δv 30 km/h.**

**Figure 4. Photographs at 1, 50 and 100 ms from tests with a belted WorldSID interacting with an inflatable curtain at 90 degrees and Δv 50 km/h.**

The results of this study, in terms of saved annual US occupants, are shown Table 2, including the ratios of incidence.

**Table 2. Estimated opportunity of far side countermeasures mitigating annual US AIS3+ and fatalities at the Δv threshold (from Bostrom et al 2008)**

| Conceptual countermeasure | Δv threshold (km/h) | Far side AIS3+ | Far side fatalities |
|---|---|---|---|
| Altered seat belt (4-point) | 0-30 | 715 (57%) | 83 (18%) |
| Side support airbags | 0-30 | 715 (57%) | 83 (18%) |
| Side curtain | 30-50 | 350 (28%) | 136 (30%) |

According to Table 2, the combination of side curtains and side support airbags alternatively altered seat belts, would if being 100% effective in the dV intervals of 30-50 and 0-30 km/h respectively save 85% of all severe injuries and 48% of all fatalities. If these countermeasures in reality fails to be 100% effective in these Dv intervals and say protects every second occupant, that is 50% effective, the combination of curtains and support airbags/altered belts would save 42% of all far side severe injuries and 24% of all fatalities. Bostrom et al 2008 concluded that the opportunity for far side countermeasures is in the same order (in terms of percent injury/fatality reduction) as common nearside and frontal impact countermeasures.

## 2.2 Passenger interaction

Real life crash analysis indicates that occupants on the struck side of a vehicle may also be injured by contact with an adjacent occupant in the same seating row. The injury consequences of occupant-to-occupant impacts can be severe, and sometimes fatal. With the support and assistance of the program Newland et al (2008) investigated the risk of such impacts by analyzing real life crashes and also evaluated the feasibility of potential countermeasures by analyzing six full scale side impacts where both front seat row seats were occupied with dummies. Examples of dummy interaction in two crash simulations are shown in Figures 5 and 6.

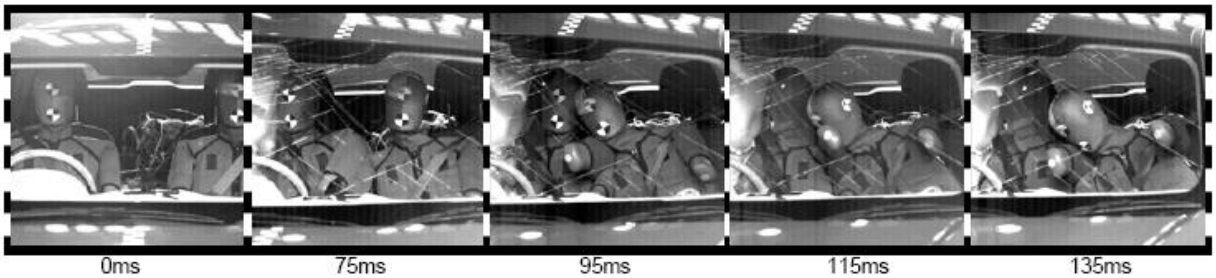


**Figure 5 – Two belted WorldSID dummies interacting in a pole impact. The dummy interaction started after the critical (in terms of injury values) near side occupant interaction with the side interior. The HIC exceeded 8000 for both dummies. From Newland et al 2008.**


**Figure 6 – Two belted WorldSID dummies interacting in a pole impact where side support airbags were present in-between the dummies. No injurious head contact occurred. From Newland et al 2008.**

The field crash analysis suggested that the risk of injury to a driver seated on the non-struck side in a side impact crash is likely to be increased by the presence of an adjacent front seat occupant. Moreover, the side support airbag (altered seat belts were not tested) was shown to be effective in preventing interaction injury in the vehicle-to-pole test.

# 3 References

The following papers influenced the work of task 7 however were not a direct part of the program.

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